

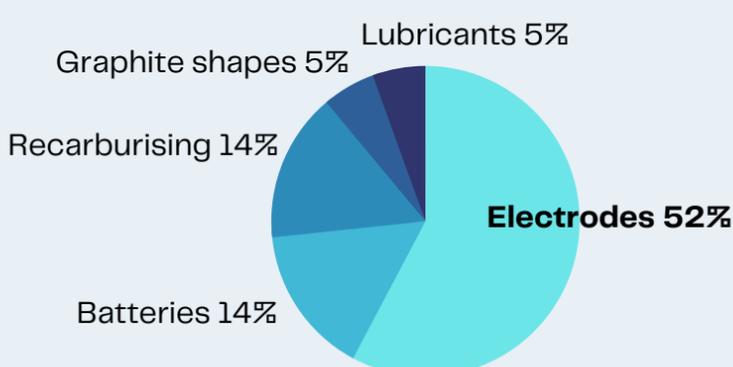
# Carbon and Graphite in the Circular Economy

Carbon and graphite products are used in the metallurgical industry (primary and secondary production) in the form and function of cathodes, anodes, electrodes, furnace linings and other refractories. They have their particular role in recycling of resources.

## Recycling of steel thanks to graphite electrodes

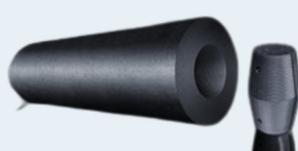
**Synthetic graphite** is needed to manufacture electrodes which are widely used in steel-recycling electric arc furnaces, refining furnaces for ferroalloy, industrial silicon, yellow phosphorus, corundum production. It is used in submerged arc furnaces and other arc furnaces that require very high temperatures.

### Synthetic Graphite by application (2021)



source: Wood MacKenzie,

## Graphite electrodes



- Large cylindrical structures composed of either petroleum-based needle coke or coal-based needle coke and other carbonaceous materials. They are used to conduct high amounts of electricity.
- The size of electrodes varies widely from 75 mm to as large as 800 mm in diameter and up to 3,600 mm in length.

- Global production of graphite electrodes in 2021 – 1.100.000 tons

- The global graphite electrode market value in 2021 – EUR 2 – 4 billion projected CAGR of 4,6% between 2022-2027

- Average graphite electrode consumption per ton of liquid steel – 4,5 kg



**China**

The largest steel producer in the world.

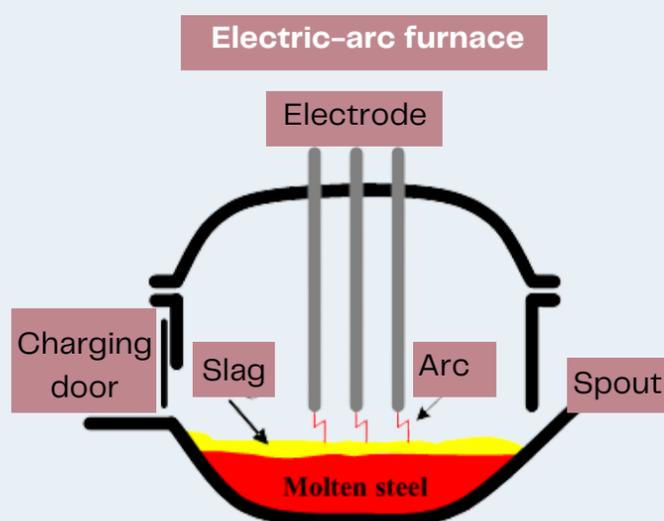
The largest share of graphite electrode consumption in the global scenario.

The largest share of graphite electrode production capacity in the globally.

## Graphite's advantages

- ✓ It is resistant to thermal shock
- ✓ It is the only material in which mechanical properties increase with temperature
- ✓ It has a low CTE (Coefficient for thermal extension) for geometrical stability
- ✓ It is easily machined
- ✓ It does not melt but sublimates at very high temperature (3.650°C)
- ✓ Its density is low

## Graphite as an enabler of steel recycling and CO2 saving



source: substech.com

Using graphite electrodes allows obtaining high temperatures needed to melt the steel scrap. It also ensures the steel qualities of the recycled steel. The tip of the electrode will reach 3.000 degrees Celsius, **half the temperature of the surface of the sun**. Graphite electrodes are an integral part of the latest steel recycling technology and given the increased use of steel in infrastructure around the world, graphite electrodes will continue to be required to save resources for the future.

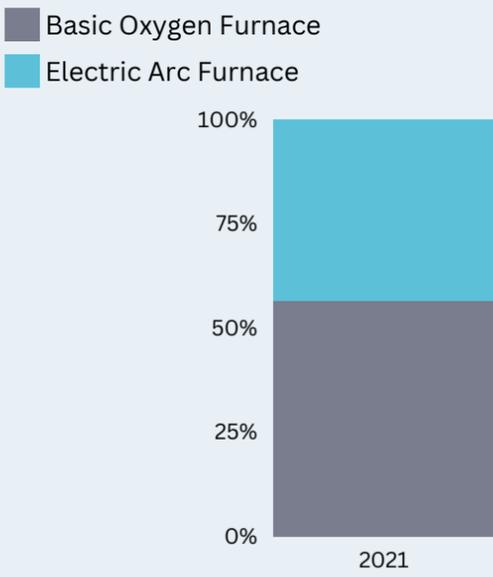


Compared to steel making via the Basic Oxygen Furnace (BOF) graphite electrodes used in EAFs contribute to a reduction of **84 million mt of CO2 emissions per year in the EU, equivalent to emissions from 28 million passenger cars.**



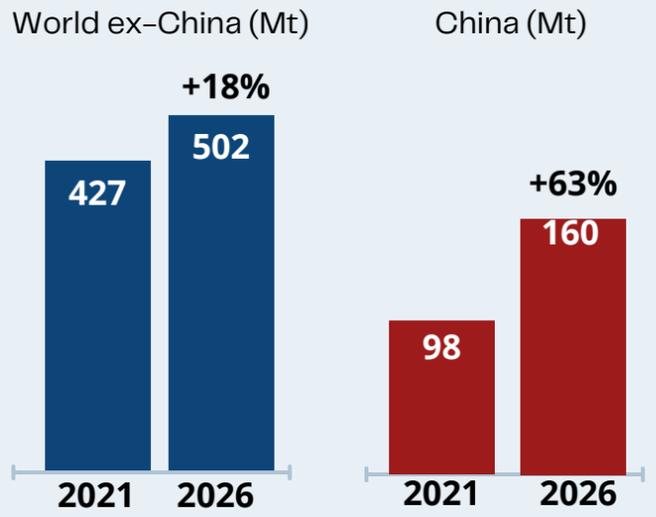
Forecast

EU crude steel output by production route



source: Eurofer

EAF steelmaking by region



source: RHI Magnesita

- 27.5 million mt of **new EAF capacity to be built in Europe** by 2035. The cost of transformation investment is estimated at US \$100 billion excluding infrastructure costs.
- In September 2021, the World Steel Association (WSA) predicted globally a share of 40–45% EAFs by 2040 limited only by scrap availability. WSA said the BOF route would be here until the end of the century. WSA predicted scrap usage growing to 22–30% (from current ~10% scrap usage) impacting the scrap supply for EAF growth.

Recycling Steel – Decarbonization Technologies

Technology	EAF with Scrap & DRI	DRI-EAF with H2
Objective	Production of all steel qualities	Replace natural gas with green H2
Approx. Co2 reduction with renewable power %	75%	95%

source: McKinsey and Hatch

Applications

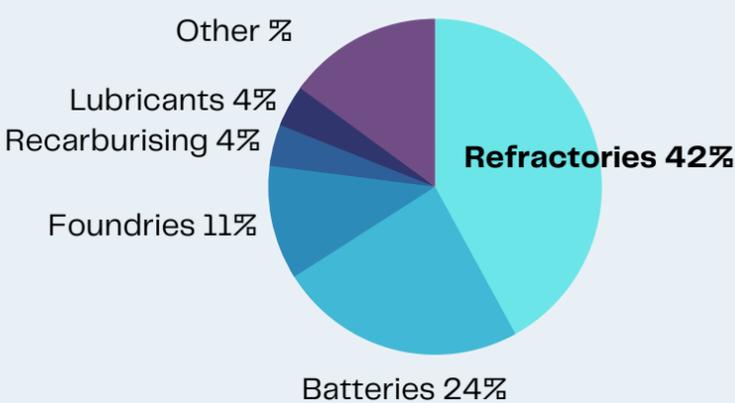


Steel is the world’s most important engineering and construction material. The many applications of steel demonstrate best the great versatility of this material. It is used in the construction, automotive and aircraft industries, heavy industrial equipment, transport infrastructure, household appliances, weapons and so on.

Steel made in Europe is the backbone of the EU’s built-up infrastructure, its economic resilience and sustainability. Steel can be recycled over and over again without loss of property, and is the most recycled material in the EU.

Graphite’s role in producing and remelting/recycling other metals

Natural Graphite by application (2021)



Refractories play a critical role in the daily operations of almost every sector of manufacturing. These materials are essential for all heat-intensive production processes. Without refractories, key industries such as steel, cement, metals, glass, energy generation, and chemicals could not function. Synthetic and natural graphite is used extensively in many ways in the refractory industry.

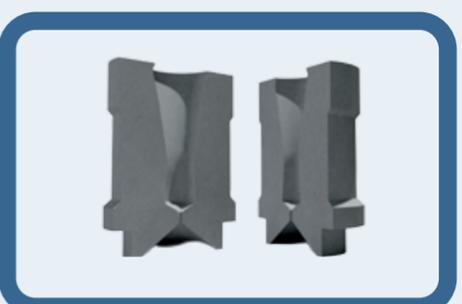
source: Wood MacKenzie, Graphite market 2021 outlook to 2050

## Graphite in refractories- examples



### Magnesia-carbon refractory bricks

MgO-C bricks are used extensively in steel making processes especially in basic oxygen furnaces, electric arc furnaces, lining of steel ladles, etc.



### Moulds and ladles for holding and handling molten metals

A broad range of extruded and vibration-moulded specialty graphite for sheets and moulds are used in the production of melt-cast zirconium oxide refractory bricks.

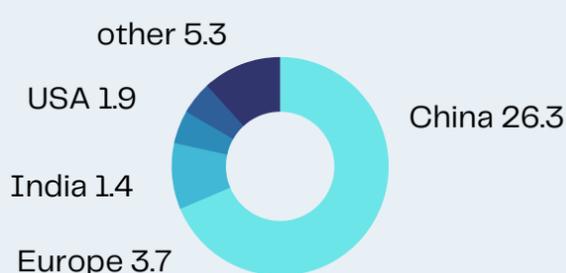


### Graphite crucibles

A graphite crucible is a container used for melting and casting non-ferrous, non-iron metals such as gold, silver, aluminium, and brass.

## Market size for graphite in refractories

### Refractory production in Mt (2021)



526.000 t of graphite used in refractories in 2021

source: Wood MacKenzie, Graphite market 2021 outlook to 2050

## Recycling of anode materials for lithium-ion batteries

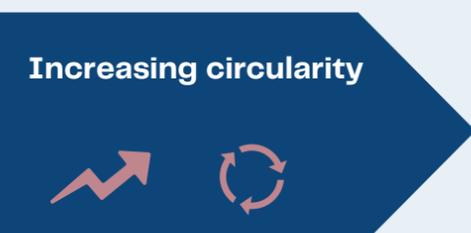


Graphite can be recycled by high temperature processing without damaging the graphite structure (it can even be improved), which makes it feasible to recycle LIB graphite anodes

It would still require a lower purification temperature than for graphitization of virgin material, making recycled graphite a product with relatively low environmental footprint.



Recycling of synthetic graphite would make batteries less dependent on high quality coke, which has been prone to volatile prices, and on imports from Asia, strengthening the internal market.



Production scrap will provide in the short- to medium-term the main supply of graphite concentrate for recycling. End-of-life batteries will eventually take over as the main source.

## Damaged electrodes and production scrap recycling

Damaged graphite electrodes are usually reprocessed to the same grade graphite electrodes. They can be used in manufacturing industry like steel and ferrosilicon smelting. Some are also reprocessed into graphite heterotypic products like graphite crucibles and some others. Milled graphite, shavings and cuttings can be used as raw material for production of carburizers.

## End-of-life production recycling

Refractory brick and linings, alumina-graphite refractories for continuous metal castings, magnesia-graphite refractory brick for basic oxygen and electric arc furnaces, and insulation brick led the way in the recycling of graphite products. Recycling of refractory graphite material is increasing, with material being recycled into various products such as brake linings and thermal insulation. Recovering high-quality flake graphite from steelmaking kish is technically feasible, but currently not practiced. The abundance of graphite in the world market inhibits increased recycling efforts. Information on the quantity and value of recycled graphite is not available.

Increased recycling of refractories offer benefits through improved waste management and the avoidance of CO2 emissions that would otherwise be released in the processing of new raw material.